

Response to reviews of the paper: "The impact of the South-East Madagascar bloom on the oceanic CO<sub>2</sub> sink" by Nicolas Metzl et al., Biogeosciences Discuss., <https://doi.org/10.5194/bg-2021-283-RC1>, 2021.

Reviewer 1, Meric Srokosz

Reviewer comments in italic, our responses in red

We thanks reviewer 1, Meric Srokosz, for his rapid and enthusiastic review.

*General Comment:*

*This is an interesting paper on the impact of the Southeast Madagascar Bloom on the oceanic CO<sub>2</sub> sink, a problem that has not been previously addressed (to my knowledge). The results are convincing but critically depend on the work of Chau et al. (2021) which is in review. As my expertise is more on the impact of physical processes on the bloom biology I am unable to to make a judgment on the work of Chau et al. (2021) regarding the reconstruction of surface pCO<sub>2</sub> and air-sea CO<sub>2</sub> fluxes on which the results in this paper so much depend. Assuming that Chau et al. (2021) is correct / passes the review process and is published, I think that application of that approach to the Madagascar Bloom provides some new insights into its role as a CO<sub>2</sub> sink. The observational aspects of the paper clearly show the strong interannual variability associated with the bloom, but the interpretation of these in terms of CO<sub>2</sub> hinges on Chau et al. (2021). In light of this I am happy to recommend publication once the Chau et al. (2021) has passed peer review and been accepted for publication, after correction of a few minor issues (listed below).*

The reviewer commented (like reviewer 2) on the fact the results critically depend on the work of Chau et al. (2021), a paper that was in review at the time we submitted our paper. We agree that the model is an important piece of the analysis as it specifically offered an estimate of the impact of the bloom on CO<sub>2</sub> fluxes over a large domain (not only along the repeated cruise tracks) and also on an annual scale (not only for one season).

The paper submitted by Chau et al (2021) was not reviewed at the time we prepared our paper. However, the reviews for their paper were posted on-line in late September and the authors responded to the reviews last November 15th. At the time of this response (3/1/2022), the paper by Chau et al (2021) is not yet accepted but a revision is on the way.

Note that when we started this analysis (last year) we explored a first version of the same model described by Denvil-Sommer et al (2019) and Chau et la (2020) and preliminary results motivated the use of such a model for our purpose. The results of the first version of the model were also successfully used in another study focused in the Mozambique Channel (Lo Monaco et al, DSR 2021) and we were confident with this approach to explore the results of the model in the South-Western Indian sector. The model developed by Chau et al (2020, 2021) is an improvement of the first version by Denvil-Sommer et al (2019). Model results are under quality control of the European Copernicus Marine Environment Monitoring Service (CMEMS) and available for public use since 2019 ([https://resources.marine.copernicus.eu/?option=com\\_csw&view=details&product\\_id=MULTIOBS\\_GLO\\_BIO\\_CARBON\\_SURFACE\\_REP\\_015\\_008](https://resources.marine.copernicus.eu/?option=com_csw&view=details&product_id=MULTIOBS_GLO_BIO_CARBON_SURFACE_REP_015_008), product DOI: <https://doi.org/10.48670/moi-00047>).

As the model has been updated, we thought it was more appropriate to use the new version of this model (Chau et al, 2021) extended to end-2019 that included the bloom anomaly well reproduced for December 2019 (Figures 10, 11).

Note also that results of the model by Chau et al (2021) have been used for global estimate of the ocean CO<sub>2</sub> sink in the last Global Carbon Budget (Friedlingstein et al, 2021; T. Chau is co-

author and results presented at COP26 last November). Similarly, results of the CMEMS-LSCE-FFNN model (Denvil-Sommer et al 2019, Chau et al 2020) were also used in the previous GCB (Friedlingstein et al, 2019, 2020). Here we show the model is relevant for regional analysis, i.e. not only a view of the global ocean carbon sink as used in the Global Carbon Project. We hope that by the time our present paper is revised, the paper by Chau et al (2021) will be accepted.

*Minor comments:*

*lines 275-277 - given that wind speed is spatially (as well as temporally) variable I am not sure how taking account of spatial variability would affect the calculations described here. Does it matter?*

Response: This is an important point, not only for air-sea CO<sub>2</sub> fluxes but also regarding the impact of the wind speed on mixing and circulation in this region and thus on biogeochemical properties (e.g. nutrients input) and fCO<sub>2</sub> distributions. To compare the fluxes between various periods (e.g. 2005 versus 2020) we looked at the wind speed for these periods; the averaged wind speed was almost the same for both periods (Supp Figure S4) and we concluded that the wind was not impacting the differences of fluxes that are mainly controlled by  $\Delta fCO_2$  (2020 versus 2005, Table 2 or Figure 4). This is also clearly revealed in the model results when comparing December 2018 and 2019 (Figure 10). Note that when using only the fCO<sub>2</sub> data from the cruises, uncertainty of the flux integrated over a large domain (not only along the cruise track) is mainly linked to the prescribed “size” of the bloom (as discussed lines 281-228). This is why we also listed the results for different areas representative of the bloom. Finally, as the wind speed is around 8 m.s<sup>-1</sup> on average, the use of a different gas transfer coefficient (the term “k” in Equations 1, 2) would not introduce a bias when comparing the fluxes for different periods as “k” is almost the same at that wind speed depending the relations used (e.g. Wanninkhof, 2014).

*Figure 3 mark positions of eddies*

Response: The reviewer suggests to mark the positions of eddies in Figure 3 and S3. The aim of these figures was to present the records of properties (fCO<sub>2</sub>, C<sub>T</sub>, A<sub>T</sub>, SST, SSS) along the cruise track in January 2020 and to highlight the contrast of fCO<sub>2</sub> and C<sub>T</sub> concentrations in the bloom (at 27°S) and south of the bloom as identified from Chl-a concentrations along the track also shown in Figure 3. As opposed to the Chl-a distribution in November 2019 (2 large Chl-a rings probably associated to Eddies, Supp Figure S1 and S2 and discussed lines 189-193 and 585-593), the Chl-a in January 2020 covered a large domain, not clearly associated to eddies (Figures 1a and S1). The gradient of properties fCO<sub>2</sub>, C<sub>T</sub> and salinity in January 2020 around 54°E (Figures 3 and S3) were clearly most pronounced around 27°S, whereas temperature did not show a specific signal (SST decreased progressively southward, Figure S3). On the other hand, salinity suggests the presence of multiple fronts localized around 26.5°S, 27°S and 28°S (Figure S3). Are these structures observed in January 2020 along the cruise track related to eddies or large scale circulation ?

Based on ADCP data recorded in January 2020 (See figure R1 in this response, a figure that was not included in the submitted manuscript) the structure of the current appeared mainly zonal with marked East/West components (i.e. not clearly associated to Eddy). The ADCP section shows a relatively strong westward current around 27°S, down to 600m. Interestingly, it seems that the SICC well observed in 2005 around 25°S (Figure S6) was not so well marked in January 2020 (with a subsurface current centered around 200m at 25°S).

We also plot the fCO<sub>2</sub> and salinity records (like original Figures 3 and S3) here along with surface current speed (figure R2 in this response). The low salinity and low fCO<sub>2</sub> around 27°S (in the bloom) were associated with the westward current; in the south, when salinity and fCO<sub>2</sub> were higher the current was also westward suggesting this is not a signal of Eddy.

To conclude, we were not able to detect Eddies along the track in January 2020 and thus we did not add any marks in Figures 3 and S3 as suggested by the reviewer. The question of the link between eddies, fCO<sub>2</sub> distribution and associated air-sea CO<sub>2</sub> flux is a relevant topic but we think it is beyond the scope of our analysis mainly focusing on the large scale (i.e. comparing data in a large domain over the period 1991-2020). Unfortunately we have no in-situ data in November 2019 that would cross the Eddy-like structures of the bloom (Figure S1, S2) as was observed during the MadEX cruise in February 2005 (Poulton et al, 2009; Srokosz and Quartly, 2013, discussed lines 298-307). On this issue (the link between eddies and bloom) we will add a few words to the conclusion to suggest this is also a relevant research topic for future in-situ studies especially in this highly complex dynamical region. Note for the editor, that concerning this specific question we contacted the reviewer to be sure that his question concerned Figure 3 and no other figures.

*Figure S2 add lat & long on axes, also Figure S6 bottom:*

Response: Latitude and longitude will be added in the maps. In Figure S2 we will also add two large circles to highlight the locations of the bloom as identified in Figure S1 for November 2019.

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References added in this response (not listed in the manuscript):

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Figure R1: Top: Meridional section (Latitude/Depth) of zonal current ( $U$  in  $\text{m}\cdot\text{s}^{-1}$ ) observed from ADCP data collected in January 2020 in the South-Western Indian Ocean (OISO-30 cruise, see the track in Bottom). A strong westward current down to 600m is identified around 27-29°S. Figure produced with ODV (Schlitzer, 2013). Bottom: Map of monthly surface current for January 2020 in the South-Western Indian Ocean showing the retroflexion of the East Madagascar Current here around 24°S (one of the forms of the EMC retroflexion defined by Ramanantsoa et al 2021) and its complex meandering structure deflecting southward and recirculating northward around 54°E. Bottom Figure produced from <https://resources.marine.copernicus.eu/> (MULTIOBS\_GLO\_PHY\_REP\_015\_004) last access, 15-Dec-2021.

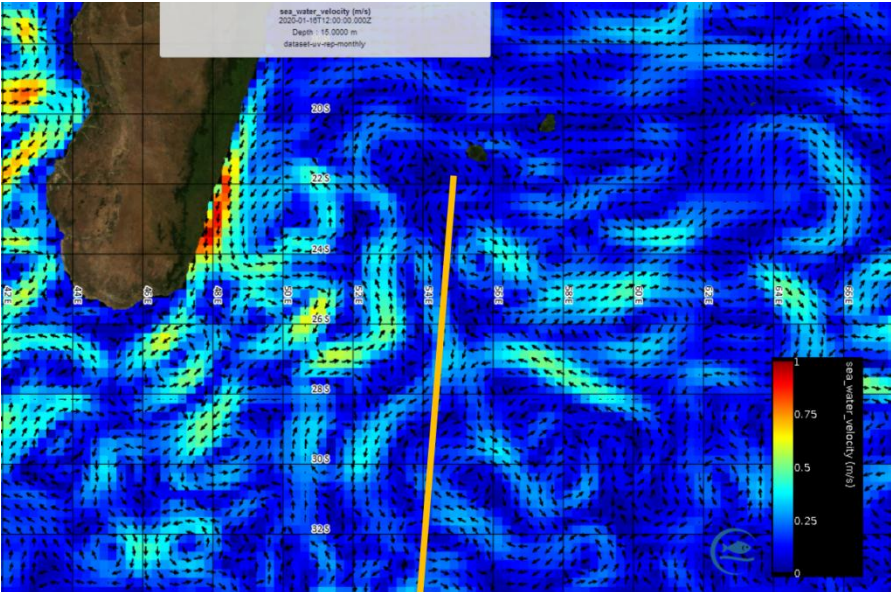
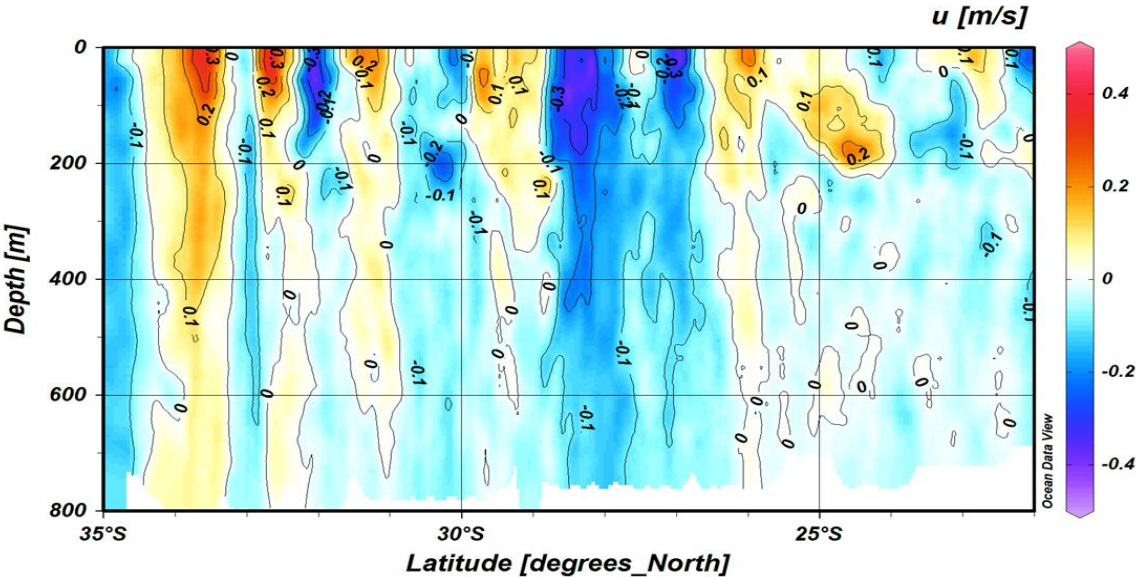


Figure R2: (a): Sea surface salinity (SSS, black circles) and zonal surface current (U cm/s, grey line, from ADCP data at 24m) in January 2020 along the OISO-30 cruise track around 54°E. (b): same as (a) for  $f\text{CO}_2$  ( $\mu\text{atm}$ ). The highest Chl-a concentration in the SEMB observed north of 27°S (Figure 3 in the Manuscript) in waters with lower salinity and low  $f\text{CO}_2$  where the current was westward ( $U < 0$ , see figure R1). Westward current was also observed around 28-29°S in high salinity and high  $f\text{CO}_2$  waters suggesting this is not a signal of an eddy.

